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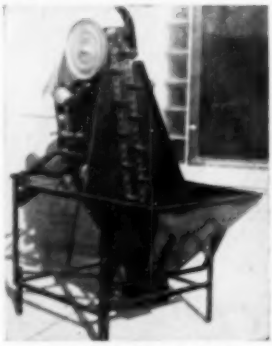

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EFFECTS OF FERTILIZER AND USE OF MAGNESIUM AND MINOR ELEMENTS ON YIELDS AND STORAGE QUALITY OF POTATOES IN BALDWIN COUNTY, ALABAMA[1]

W. A. Johnson,[2] John I. Wear,[3] and Frank Garrett[4]

Early potato production in Alabama is concentrated in a small area in the southwestern part of the state. From 15,000 to 30,000 acres are planted in the southern part of Baldwin County; the adjoining counties of Mobile and Escambia produce a small portion of the crop. The average yields of No. 1 potatoes in recent years have ranged from 8,500 to 10,000 pounds per acre (1).

In the past, most of the fertilizer has been applied in one application. In recent years more and more farmers are using split applications of approximately two-thirds under and one third one month after planting. The average total fertilizer application is approximately 2,500 pounds per acre, and 80 to 90 per cent of the fertilizer used has been a 4-10-7 grade (1).

In the early 1940's when mature plants began to appear chlorotic, it was first thought that this was due to a deficiency of magnesium. Chlorosis was found to be partially due to a deficiency of nitrogen (2), although magnesium was also deficient. Most of the farmers are now applying fertilizer-containing magnesium.

In 1952 tests were begun on farmer's fields in Baldwin County to evaluate some of the fertilizer practices, to obtain some information regarding kinds and rates of fertilizer for side applications, and to determine the effect of applications of magnesium and minor elements.

Experimental Methods

Field tests were conducted on Coastal Plain soils ranging in texture from loamy sand to very fine sandy loams. These represent the light to the heavier soils of this section used for potato production. In this paper the loamy sands and sandy loams are referred to as the light-textured soils and the very fine sandy loams as the heavy-textured soils.

Treatments in all tests were replicated three times. All plots were 1/120 acre in size and consisted of four rows. Yields were recorded from the two inside rows. During the first two years, the cooperating farmers made the initial application of fertilizer, cultivated, applied insecticides and disease control measures, and dug the potatoes. The investigators located the plots, applied the side applications of fertilizer, and harvested, graded, and weighed the potatoes. In 1954 however, the investigators also made the initial application of fertilizer.

In 1952, tests consisting of nine treatments, were conducted at five locations. A standard application of 1,800 pounds per acre of 4-10-7 was applied at time of planting to all plots. The treatments consisted of the

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standard fertilizer with and without side applications of (1) nitrogen, (2) nitrogen and potash, (3) complete fertilizer, and (4) applications of magnesium and minor elements. Yields of No. 1, 2, and 3 grade potatoes were recorded. Only the yields of No. 1 grade potatoes are herein reported. Immediately after the initial fertilization, one-half of the magnesium sulfate and all minor elements were applied in the fertilizer band and the other half of the magnesium sulfate was added in the side application of fertilizer. Magnesium in the form of magnesium sulfate was added at the rate of 40 pounds of MgO per acre. The minor element mixture used consisted of 10 pounds of borax, 10 pounds of zinc sulfate, 10 pounds of manganese sulphate, 5 pounds of copper sulphate, and 1 pound of sodium molybdate per acre.

In 1953 tests were conducted at three locations. Since Irish potatoes require only a small amount of nitrogen during the early growing season and since there is a growing demand and use of higher analysis fertilizers, applications of a 4-12-12 fertilizer at the rate of 1,000 pounds per acre were used at time of planting, and an 8-8-8 fertilizer was used for side applications. Additional treatments for 1953 included rates of side applications of complete fertilizer and a general farmers' rate that consisted of 1,800 pounds of 4-10-7 at planting and a side application of 700 pounds of 6-8-8 per acre.

In 1954 tests were conducted at three locations. The base fertilizer rate of 1,000 pounds of 4-12-12 was applied by the investigators. In two of the tests, 800 pounds of 8-8-8 were applied at planting time with the base application of 4-12-12.

During the time in which the tests were conducted, the rainfall was unusually variable. The rainfall data by months or parts of months, which included the periods from the time potatoes were planted to the time of harvest, are given in table 1. These data were taken from the weather station at Fairhope, Alabama. Rainfall for the growing period was above normal in 1953, and approximately one-half of this amount fell in April. The rainfall for 1952 was below normal and in 1954 it was the lowest recorded for the period.

Results

Yields of No. 1 potatoes by treatments, locations, and soil textures in 1952, 1953 and 1954 are presented in tables 2, 3, and 4, respectively.

Effects of Side Application of Nitrogen

In 1952, 32 pounds of N applied as a side application, as compared to no side application, increased the average yields of No. 1 potatoes

Table 1.—*Rainfall during growing period of potatoes.*

Years	Dates		Rainfall from Time Potatoes Were Planted to Time of Harvest				
	Planted	Harvested	Feb.	Mar.	Apr.	May	Total
			In.	*In.*	*In.*	*In.*	*In.*
1952	Feb. 11	May 14	5.42	4.01	3.38	0.00	12.81
1953	Jan. 31	May 11	5.84	4.70	10.19	0.89	21.62
1954	Feb. 4	May 13	1.93	2.88	1.14	0.33	6.28

TABLE 2.—*Effects of magnesium, minor elements, and side applications of fertilizers on yields of No. 1 potatoes, 1952.*

Treatments					Yields of No. 1 Potatoes per Acre by Soils and Farms[3]					
Fertilizer per Acre			Mg.[1]	Minor[2] Elements	Light-textured Soils			Heavy-textured Soils		Average Yields for the Five Locations
Under 4-10-7	Side				Sharrot's	Khnote's	Cleverdon's	Parry's	Brock's[4]	
	Amount	Kind								
Pounds	*Pounds*				*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1800	0	O	+	+	4,961	8,160	9,521	6,559	7,361	7,312
1800	32	N	+	+	7,440	10,399	10,039	6,079	7,601	8,312
1800	32	N	+	+	8,239	12,401	12,080	5,719	7,999	9,272
	56	K_2O								
1800	800	4-10-7	+	+	7,759	13,361	11,201	7,721	8,801	9,769
1800	800	4-10-7	O	+	6,641	11,921	9,760	7,039	8,239	8,720
1800	800	4-10-7	+	+—B	8,441	12,079	12,480	5,801	7,759	9,312
1800	800	4-10-7	+	+—Zn	8,239	12,161	12,881	7,639	8,719	9,928
1800	800	4-10-7	+	O	7,200	14,160	12,079	6,600	7,560	9,520
LSD .05 Level					1,310	3,324	2,385	NS	1,752	921
.01 Level					1,807	4,579	3,288	NS	2,412	1,226

[1]Magnesium applied as $MgSO_4$ (28 per cent MgO) at the rate of 143 pounds per acre for an equivalent amount of 40 pounds of MgO per acre. The magnesium was applied with the mixed fertilizer.
[2]Minor element mixture consisted of 10 pounds of borax, 10 pounds of $ZnSO_4$, 10 pounds of $MnSO_4$, 5 pounds of $CuSO_4$, and 1 pound of Na_2MoO_4 per acre, applied at time of applying the fertilizer.
[3]Farms where tests were conducted are designated by names of farm owners.
[4]The Sebago variety was used in test at Brock's farm, whereas the Triumph variety was used in tests on other farms.

TABLE 3.—*Effects of magnesium, minor elements, and side applications of fertilizers of yields of No. 1 potatoes, 1954.*

Treatments						Yields of No. 1 Potatoes per Acre by Soil Types and Farms[3]			
Fertilizer per Acre				Mg.[1]	Minor Elements[2]	Light-textured Soils		Heavy-textured Soil	Average of Three Locations
Under		Side				Garrett's	Parry's	Khnote's[4]	
Amount	Kind	Amount	Kind						
Pounds	*N-P-K*	*Pounds*				*Pounds*	*Pounds*	*Pounds*	*Pounds*
1000	4-12-12	0	0	+	0	8,640	15,600	7,920	10,720
1000	4-12-12	64	N	+	0	11,239	19,121	9,720	13,360
1000	4-12-12	64	N	+	0	11,239	18,319	8,959	12,839
		64	K_2O						
1000	4-12-12	400	8-8-8	+	0	10,999	17,359	10,320	12,893
1000	4-12-12	800	8-8-8	+	0	11,040	17,721	9,900	12,887
1000	4-12-12	1200	8-8-8	+	0	11,681	19,200	8,719	13,200
1000	4-12-12	800	8-8-8	0	0	10,639	16,961	10,200	12,600
1000	4-12-12	800	8-8-8	+	+	12,120	18,720	11,340	14,060
1800	4-10-7	700	6-8-8	+	0	11,959	18,559	10,399	13,639
LSD .05 Level						1,742	NS	NS	1,390
.01 Level						2,388	NS	NS	1,865

[1]Magnesium applied as $MgSO_4$ (28 per cent MgO) at the rate of 143 pounds per acre for an equivalent amount of 40 pounds of MgO per acre. The magnesium was applied with the mixed fertilizer.
[2]Minor element mixture consisted of 10 pounds of borax, 10 pounds of $ZnSO_4$, 10 pounds of $MnSO_4$, 5 pounds of $CuSO_4$ and 1 pound of Na_2MoO_4 per acre, applied at time of applying the fertilizer.
[3]Farms where tests were conducted are designated by names of farm owners.
[4]The Sebago variety was used in test in Khnote's farm, and Triumph was used in test on other farms.

TABLE 4.—*Effects of magnesium, minor elements, and side applications of fertilizers on yields of No. 1 potatoes, 1953.*

Treatments						Yields of No. 1 Potatoes per Acre by Soil Types and Farms[3]			
Fertilizer per Acre				Mg.[1]	Minor Elements[2]	Light-textured Soil	Light-textured Soil (Deep Phase)	Heavy-textured Soil	Average of Two Light-textured Soils
Under		Side							
Amount	Kind	Amount	Kind			Garrett's No. 1	Garrett's No. 2	Lyrene's[4]	
Pounds		*Pounds*				*Pounds*	*Pounds*	*Pounds*	*Pounds*
1000	4-12-12	0	0	+	0			13,480	
1000 800	4-12-12 8-8-8	0	0	+	0	9,080	6,540	—	7,810
1000	4-12-12	64	N	+	0	7,820	6,300	13,960	7,060
1000	4-12-12	400	8-8-8	+	0	7,480	6,040	14,612	6,760
1000	4-12-12	800	8-8-8	+	0	9,540	5,830	14,760	7,685
1000	4-12-12	1200	8-8-8	+	0	8,760	5,820	14,520	7,290
1000	4-12-12	800	8-8-8	0	0	7,620	5,280	13,760	6,450
1000	4-12-12	800	8-8-8	+	+	9,040	4,520	12,900	6,780
1800	4-10-7	700	6-8-8	+	0	7,680	5,740	13,440	6,710
LSD .05 Level						1,272	NS	NS	958
.01 Level						1,735	NS	NS	1,308

[1]Magnesium applied as $MgSO_4$ (28 per cent MgO) at the rate of 143 pounds per acre for an equivalent amount of 40 pounds of MgO per acre. The magnesium was applied with the mixed fertilizer.

[2]Minor element mixture consisted of 10 pounds of borax, 10 pounds of $ZnSO_4$, 10 pounds of $MnSO_4$, 5 pounds of $CuSO_4$, and 1 pound of Na_2MoO_4 per acre, applied at time of applying the fertilizer.

[3]Farms where tests were conducted are designated by names of farm owners.

[4]La Soda variety was used in test on Lyrene's farm and Triumph was used on the other two farms.

1,745 pounds per acre on three light-textured soils, but showed no significant increase on the two heavier textured soils; all treatments received 1,800 pounds of 4-10-7 at time of planting. The average increase for the five locations was 1,000 pounds per acre, which was significant at the 0.05 level.

In 1953, 64 pounds of N applied as a side application increased the average yields 3,000 pounds per acre on two light-textured soils and 1,800 pounds per acre on the heavy-textured soil. In 1954, 64 pounds of N as a side application increased the yield 480 pounds on the heavy-textured soil. Treatments at planting time in 1953 and 1954 were 1,000 pounds each of 4-12-12 per acre.

Effects of Side Applications of a Complete Fertilizer

In 1952, 800 pounds of 4-10-7 applied as a side application in addition to the 1,800 pounds applied at time of planting increased the yield of No. 1 potatoes 3,226 pounds per acre on three light-textured soils and 1,301 pounds on two heavier textured soils. The average increase for the five locations was 2,457 pounds, which was significant at the 0.01 level.

In 1953, 800 pounds of 8-8-8 applied as a side application in addition to the 1,000 pounds of 4-12-12 applied at the time of planting increased the yields an average of 2,261 pounds on two light-textured soils and 1,980 pounds on the heavier textured soil. The average increase for the three tests was 2,167 pounds of No. 1 potatoes per acre, which was significant at the 0.01 level. In 1954, 800 pounds of 8-8-8 applied as a side application in addition to the 1,000 pounds of 4-12-12 applied at time of planting on a heavy-textured soil increased the yield 1,280 pounds.

Comparison of Side Applications of Nitrogen, Nitrogen and Potassium, and Complete Fertilizer

The average yields in 1952 on three light-textured soils from side applications of 32 pounds of N, 32 pounds of N and 56 pounds of K_2O, and 800 pounds of 4-10-7 were 9,293, 10,880, and 10,774 pounds of No. 1 potatoes, respectively. The average results on the two heavier soils from the same treatments were 6,840, 6,859, and 8,261 pounds, respectively. Average yields from the five tests were increased 1,457 pounds per acre from the side application of 800 pounds of 4-10-7 compared with that from the side application of 32 pounds of N. This increase was highly significant.

In 1953 a side application of 64 pounds of nitrogen produced yields as high as those from side applications of either the nitrogen-potash mixture or the complete fertilizer regardless of soil texture.

In 1954 there was no difference in yields between treatments on a deep phase, light-textured soil from the use of different side applications of fertilizer as shown in table 4. On the sandy loam soil, the side application of 800 pounds of 8-8-8 produced 1,720 pounds per acre more than that from the use of 64 pounds of N; this increase was highly significant. On the heavier soil, the side application of complete fertilizer produced only 800 pounds per acre more than a side application of N.

Effects of Rates of Fertilizer Used as Side Applications on Yields

When 1,000 pounds of 4-12-12 was applied at time of planting, a

side application of 800 pounds of an 8-8-8 resulted in an increase in yield. It is shown in tables 3 and 4 that the yields were not significantly different when the rates of fertilizer applied as a side application were 400, 800, and 1,200 pounds per acre.

Comparison of Fertilizer Practices

It is a common practice in the potato-growing area in Baldwin County to apply 1,800 pounds of 4-10-7 at time of planting and 700 to 800 pounds of 4-10-7 or 6-8-8 fertilizer as a side application. In 1953 and 1954, the standard fertilizer treatment used in tests was 1,000 pounds of 4-12-12 at planting and 800 pounds of 8-8-8 as a side application. The tests in 1953 and 1954 included a "farmer treatment" consisting of 1,800 pounds of 4-10-7 at time of planting and 700 pounds of 6-8-8 as a side application. The average yields of No. 1 potatoes from the standard treatment in 1953 and 1954 were 11,465 pounds as compared with 11,296 pounds per acre for the "farmer treatment"; therefore, there was no material difference in yield between the two treatments.

Results indicated that 1,000 pounds of 4-12-12 at time of planting is as efficient in producing high yields of potatoes as 1,800 pounds of 4-10-7. This reduction in rate might well be justified, especially if soil tests show that there is a high residual amount of phosphorus and potash in the soil.

Effects of Magnesium on Yields

In 1952 when magnesium was applied at the rate of an equivalent to 40 pounds of MgO per acre, the increase ranged from 1,118 to 1,440 pounds per acre on the sandy soils and from 562 to 682 pounds on the heavier textured soils. The average increase from the five tests in 1952 was significant at the 0.05 level. In 1953 the increases due to magnesium ranged from 401 to 760 pounds per acre on the two sandy soils, with no increase in yields on the heavier textured soil. The average increases in yields in 1954 ranged from 550 to 1,920 pounds per acre on the two sandy soils and 1,000 pounds per acre on the heavier textured soil; the 1,920- and 1,000-pound increases were significant at the 0.05 level.

On a total of 11 field tests conducted in 1952, 1953, and 1954, 10 of these tests resulted in higher yields from use of magnesium. In six tests the increases due to the application of magnesium were significant at the 0.05 level.

Effects of Minor Elements on Yields

In the 11 field tests conducted during the 3 years, applications of a combination of minor elements gave no significant increases in yields.

Relationship of Levels of Phosphorus and Potassium in Soil to Yields

In 1952, and 1954, soil samples were taken from plots before fertilizer was applied. Determinations for P_2O_5 and K_2O were made by the Soil Testing Laboratory at Auburn. The levels of P_2O_5 and K_2O and potato yields from standard treatments are given in table 5. The data indicate a relation between production and levels of residual P_2O_5 and K_2O in soil before planting. The fields with high levels of residual P_2O_5 and K_2O produced higher yields than fields with high levels of residual P_2O_5 and low levels of K_2O. Because of limited data the results are not conclusive.

TABLE 5.—*Available phosphorus and potassium content of soils with yields of potatoes from standard treatment.*

Farm	Soil Type	Year	Soil Test[1]		Yields per Acre from Standard Treatment[2]	
			Available P_2O_5	Available K_2O	No. 1	Total
			Pounds	*Pounds*	*Pounds*	*Pounds*
Sharrot	Norfolk sl	1952	286 (High)	70 (Low)	7,759	9,079
Khuse	Norfolk sl	1952	177 (High)	192 (Medium)	13,361	14,280
Cleverdon	Norfolk fsl	1952	229 (High)	110 (Medium)	11,201	13,042
Farry	Malborough vfsl	1952	220 (High)	62 (Low)	7,721	9,761
Brock	Ruston vfsl	1952	252 (High)	76 (Low)	8,801	10,402
Khuse	Malborough vfsl	1953	220 (High)	140 (Medium)	9,900[3]	12,060[3]
Parry	Norfolk sl	1953	177 (High)	192 (Medium)	17,721	20,678
Garret	Faceville fsl	1953	183 (High)	128 (Medium)	11,040	12,409
Lyrene	Faceville vfsl	1954	351 (High)	248 (High)	14,760	15,825
Garret No. 1	Malborough sl	1954	99 (Medium)	68 (Low)	9,540	10,830
Garret No. 2	Ruston ls	1954	121 (Medium)	51 (Low)	5,830	7,050

[1]Determined by Soil Testing Laboratory at Auburn. Samples were taken before fertilizer was applied and crops planted.
[2]Standard treatment in 1952 consisted of an application of 1,800 pounds of 4-10-7 at time of planting and 800 pounds per acre to side; in 1953 and 1954 it consisted of 1,000 pounds of 4-12-12 at time of planting and 800 pounds per acre of an 8-8-8 to side after plants were up to stand.
[3]Potatoes in this field were planted 3 weeks later than potatoes in other tests in 1953 and harvested at the same time as other tests were harvested; therefore shorter growing period had some effect on yields.

These data indicate that soil analysis before planting should be of value in determining the amounts of fertilizer needed for high production on old potato soils.

Effect of Fertilizer Treatments on Keeping Quality in Storage

In 1952 samples of potatoes were taken from each plot of each treatment of five tests conducted for keeping quality tests in storage. Before storage, five potatoes from each sample were tested for firmness by puncturing each side of each potato with and without peeling with a 5/16-inch plunger, and measuring the pounds of pressure for each puncture. After storage of five weeks similar records were taken of the stored potatoes. A second lot of potatoes was weighed before and after storage to measure weight loss. The data obtained show that the different treatments had no effect on firmness of potatoes before or after storage. They also show that the treatments did not make any difference in weight loss during the storage period.

SUMMARY

A total of 11 field tests on potato production was conducted in 1952, 1953, and 1954 in different fields in Baldwin County. The purpose of these tests was to evaluate fertilizer practices and to obtain information regarding kinds of fertilizer for side applications, rates of fertilizer for side applications, and the applications of magnesium and minor elements. These tests were conducted on Coastal Plain soils ranging from light to heavy textured.

The following results were obtained:

(1) The average yields of No. 1 potatoes for the 3-year period with the standard fertilizer treatment were 10,922 pounds from the light-textured soils and 10,295 pounds per acre from the heavy-textured soils.

(2) Side applications of nitrogen increased yields of No. 1 grade potatoes 2,272 pounds per acre on the light-textured soils and 510 pounds per acre on the heavy-textured soils.

(3) Side applications of 800 pounds of complete fertilizer increased yields of No. 1 potatoes 2,840 pounds per acre on the light-textured soils and 1,465 pounds per acre on the heavy-textured soils.

(4) Applications of magnesium sulphate increased the yield of No. 1 potatoes 1,030 pounds per acre on the light-textured soils and 486 pounds on the heavy-textured soils.

(5) No significant increase was obtained from applications of a minor element mixture consisting of borax, zinc sulphate, manganese sulphate, copper sulphate, and sodium molybdate.

(6) When 1,000 pounds of 4-12-12 was applied at time of planting, there was no significant difference between yields from side applications of 400, 800, and 1,200 pounds of complete fertilizer per acre.

(7) The yields of No. 1 potatoes from an application of 1,000 pounds of 4-12-12 applied at time of planting plus 800 pounds of 8-8-8 as a side application was 11,465 pounds. This was compared with 11,296

pounds per acre from 1,800 pounds of 4-10-7 at time of planting plus 700 pounds of 6-8-8 as a side application. The latter is a common fertilizer practice among the potato growers.

(8) Limited data from soil tests indicate that there is some relation between production and levels of residual P_2O_5 and K_2O in soil before planting. The fields with high levels of residual P_2O_5 and K_2O produced higher yields than fields with high residual P_2O_5 and low levels of K_2O; the same amount of fertilizer was applied to potatoes in all fields.

(9) The treatments used in this test did not affect the keeping quality of potatoes in storage.

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and

(Unpublished results of test conducted at the Gulf Coast Substation, Fairhope, Ala.)

CHEMICAL CONTROL OF SPROUTING IN WHITE POTATOES[1,2]

GERARDO PERLASCA[3]

INTRODUCTION

The legislation concerning the use of sprout inhibitors varies in different localities. Some State Governments have no regulations, whereas in others, *e.g.* California, chemicals used as sprout inhibitors must be registered before they are offered for sale and labeled in accordance with certain requirements. Manufacturers must prove that they are valuable for the purpose described and have no deleterious effect if the product is used for human consumption. The Federal Pure Food and Drugs Law considers the addition of any substance to food illegal unless it is established that there is no toxic effect and residues are within established tolerance limits.

Several chemicals are now available which are very effective and satisfactory in preventing sprout formation and which may have great value in the future. Until tolerance limits are set up the use of sprout inhibitors on a commercial scale should be delayed.

Several millions of bushels of potatoes are lost every year from excessive sprouting and shrivelling in common storage. Sprouting toward the end of the storage season detracts from the appearance of the potatoes and lowers their value. If more than 10 per cent of the potatoes in a lot have sprouts longer than $\frac{3}{4}$ inch they are no longer considered U.S. No. 1.

Sprouting can be reduced by storing potatoes at temperatures of 39°-42° F. Low temperature storage, however, does not meet the requirements of potato processors, chippers or dehydrators, since a dark-colored product and excessively sweet taste are associated with the high reducing sugars content which develops at low temperatures. Potatoes from cold storage must be kept several weeks at a temperature above 70° F. before dehydration or processing, in order to allow sugars to be converted to starch.

Although high temperature storage prevents accumulation of reducing sugars, excessive sprouting takes place, and as the storage temperature increases the rest period is shortened. It has been necessary, therefore, to find a way to keep tubers dormant at temperatures at which no accumulation of reducing sugars occurs. For seed stock the treatment must be of temporary effectiveness only and cause no injury to the buds. The necessity for an effective method of sprout inhibition without dele-

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ferious side effects, such as excessive weight loss, off flavors and color, was realized particularly by dealers in table stock, by growers, and by manufacturers of potato chips.

Elmer (*26, 27*) observed that when potatoes and apples were stored together, sprout growth on potato tubers was markedly reduced by a volatile gas emanating from the apples. Later the gas was recognized to be ethylene. Following both this discovery and the work of Guthrie concerning effects of various growth regulators on the sprouting of potato tubers, much work has been done and an impressive number of papers dealing with methods of inhibition of sprouting have been published in several countries.

The present review is limited to chemical methods of sprout inhibition since they are of greatest practical interest. The more widely used chemicals are discussed in alphabetical order. Except for those on toxicity, papers will be reviewed in chronological order.

Review of Literature

Dormancy as Affected by Temperature, Humidity, and Variety

The breaking of dormancy in potato tubers, after an initial rest period, is largely dependent upon the storage temperature (Wilson and McKee, *80*). At 38° F. the tubers will remain dormant almost indefinitely, at 40° F. the eyes will swell without sprout development, and at 42° F. sprout development will be observed only after several months. At higher temperatures of storage, dormancy is shortened and the rate of sprouting increased.

Dormancy was considered as a varietal character by Wright and Whiteman (*85*) and, despite the large influence of temperature, potato varieties differ markedly in their dormancy.

Emilsson (*28*) considered the length of the rest period as a varietal characteristic relatively independent from cultural conditions. In certain varieties storage temperatures of 68° F. and 32° F. considerably shortened the rest period as did high (100 per cent) relative humidity compared with low (60 per cent).

Indoleacetic acid (IAA)

Guthrie (*39, 40*) cut Irish Cobbler potatoes in pieces having one eye weighing about 10 gms., and soaked them from 1 to 7 days at 50° F. in a solution of 25-100 mgs. of IAA per 100 cc., neutralized with 5.77 cc. N/10 NaOH. These showed no sprouting after 40 days, whereas the controls sprouted almost completely.

Smith *et al.* (*73*), using the Sebago variety, reported that 1-4 applications of IAA at a concentration of 150 ppm. applied at a rate of 55-110 gallons per acre at several stages of growth, did not affect plants, yields, specific gravity or reducing sugars content of tubers after 11 weeks at 41° F., as compared with untreated controls. After 3 months' storage at 50° F. tubers of sprayed plants showed significantly less sprouting than did tubers of untreated plants.

Summary

Although Guthrie showed that indoleacetic acid had sprout prevention

properties, the treatment was not practicable since to be effective a relatively large amount must be introduced into the tissues. Spraying in the field was attempted, but sprout inhibition was not complete. Other chemicals have proved more practical.

Isopropyl-N-phenylcarbamate (IPPC) and Related Compounds

Rhodes *et al.* (68) found that IPPC gave excellent sprout inhibition for 6-7 months under field conditions on 5 varieties. In many cases, control of sprouting was complete and date of application had no noticeable effect. Tubers were treated with 1 per cent IPPC in an inert filler at a rate of approximately 72 gms. per bushel, placed in sacks and enclosed at random in field clamps in autumn. In inhibition of sprouting IPPC proved to be far superior to 2 per cent MENA used in an inert filler at a rate of 72 gms. and 144 gms. per bushel.

Downie (19) concluded, after several experiments, that IPPC gave best results with varieties commonly grown in South Australia. Used as a 2 per cent dust (37 gms. per bushel) it kept the tested varieties completely free from sprouts for 5 months and reduced weight losses to a minimum. The chemical was equally efficient on early varieties such as Sebago and on late varieties, namely, Snowflake, *etc.* There were no undesirable effects on appearance and cooking qualities, and treated tubers were suitable for sale as No. 1 grade after removal from storage.

Marth and Schultz (56) found that 3-Chloro-IPPC applied as a 1 per cent dust in talc was extremely effective as a sprout inhibitor, and much better than either IPPC, 2,4,5-T, or MH, the latter applied to the surface of tubers. Dormant Katahdin potatoes were stored at 40°-50° F. for approximately 3 months. Tubers were then treated, placed in paper bags, sealed, and stored for 2 months at 40°-50° F. No sprouts developed after 4 months at 70°-75° F. Where used as a spray on the top of the potato plants, 3-Chloro-IPPC was not effective. This may have been caused by evaporation of the chemical and therefore insufficient translocation to the tubers. Tubers stored continuously at 707°-75° F. after a water-dip treatment in a 1 per cent solution of the chemical remained completely dormant for 71 days. In May water suspensions of 0.5 per cent or 1 per cent of 3-Chloro-IPPC (1 gallon per 360 lbs. of tubers) were sprayed on each layer of potatoes as they were piled. The treatment prevented further sprouting as well as checking growth of sprouts which developed before the treatment. This effect offers a possible means to control the source of late blight infection from potato waste piles.

Dettweiler (16) found that IPPC as a 5 per cent dust (54 gms. per bushel) gave almost complete control of sprouting for 3-4 months. Treated tubers sprouted only 0.5 per cent of the controls, considering the latter as equal to 100 per cent.

When applied as a 1 per cent dust (approximately 73 gms. per bushel) on the Sebago variety, IPPC completely inhibited sprouting after 6 months (Edwards, 21). Sebago variety is a poor keeper in South Australia. This treatment produced no undesirable effect on cooking quality or appearance.

Mattingley and Downey (57) found that IPPC as a 2.4 per cent

dust (37 gms. per bushel) prevented sprouting of tubers of all varieties commonly grown in Victoria, Australia, and kept the loss of weight at 10 per cent. Controls had sprouts 6-9 inches long and lost 23 per cent of the original weight. IPPC was not considered suitable for application to seed potato.

SUMMARY

Several reports from England, Australia and the U.S. mention IPPC as the most effective sprout inhibitor applied to tubers either as a dust, a water-dip, or a spray. The chemical seems equally effective on early or late varieties. It is considered non-toxic and it does not impart to potatoes any undesirable characteristics. IPPC and 3-Chloro-IPPC evaporate readily at 77° F., a property which is advantageous in the treatment of potatoes for seed, but which necessitates avoiding ventilation in storage and makes them non-effective as foliage sprays. Until further results are obtained, IPPC is not considered suitable for the treatment of seed potatoes, and the use of potatoes treated with either IPPC or 3-Chloro-IPPC as food is not yet recommended. In this review no reports have been found on the effect of IPPC and 3-Chloro-IPPC on reducing sugars content and breakdown of treated tubers in storage.

Maleic hydrazide (MH)

Schoene and Hoffman (71) found that MH had a pronounced but temporary inhibiting effect on plant growth.

Kennedy and Smith (44) applied MH at several concentrations to potato vines 6, 8, 10, and 12 weeks before harvest. A spray of 1000 ppm at 145 gallons per acre 6 weeks before harvest controlled sprouting satisfactorily in storage and significantly reduced loss in weight after 4 months in storage at 50° F. Earlier applications caused injury to foliage and many tubers were of small size and unmarketable.

Similar results were obtained by Knapp (47) with early applications. MH treatment did not prevent sprouting of the seed potatoes the following spring.

Marshall and Smith (54) found that the dip technique had little effect on sprout inhibition, whereas the toothpick technique, *i.e.* inserting toothpicks soaked in MH into the tubers, was quite successful in sprout prevention.

Wittwer and Paterson (83) recommended the application of MH 2-6 weeks before harvest at a concentration of 2500 ppm applied at a rate of about 150 gallons per acre. Sprouting of the varieties Irish Cobbler and Pontiac was completely inhibited for 7 months at 55° F. whereas the controls were a complete loss.

Salunkhe and Wittwer (69) determined that Irish Cobbler potatoes subjected to a foliar spray of MH 2500 ppm 7 weeks before harvest and kept 7 months at 45°-55° F. showed a higher specific gravity and produced potato chips of better quality, color, flavor, and texture than the controls.

Paterson and Wittwer (62) reported that sprouting of Irish Cobbler and Pontiac potatoes was completely inhibited during 7 months' storage at 45° F. and 55° F. by spraying plants with 2500 ppm MH 4-6 weeks before harvest.

Paterson *et al.* (63) demonstrated that a single foliar spray of MH 2500 ppm plus 0.1 per cent Dreft as wetting agent applied 4-7 weeks

before harvest kept tubers in excellent condition during 7 months of storage at 45° F. and 55° F., and nearly eliminated sprouting without causing tuber injury. The authors found MH more effective than either a foliar treatment of 2,4,5-T at 200 ppm 2 weeks before harvest, or a post-harvest application of the methyl ester of alpha-Naphthaleneacetic acid at 0.9 gms. per bushel. No shrivelling was observed and little or no quality deterioration or reduction in yield of U.S. No. 1 potatoes. MH-treated tubers stored at 45° F. produced lighter colored chips due to lower reducing sugars content. Also non-reducing sugars content was lower in treated tubers.

Highlands *et al.* (43) sprayed Kennebec and Katahdin potatoes 3, 4, and 5 weeks before harvest with MH at 1000 and 2500 ppm at the rate of 150 gallons per acre. After 6 months of storage at 40° F. no significant difference was found in reducing sugar accumulation and chip color or appearance as compared with the controls.

Levi and Crafts (48) studied the toxicity of MH in California soils. They found indications that the chemical decomposes fairly rapidly under warm, moist conditions and can act as a fertilizer. Greenhouse experiments showed that MH, if used in large quantities, will sterilize the soil against plant growth. However, it decomposes too readily under the conditions mentioned to be considered an effective temporary soil sterilant.

Wittwer (82) estimated residues of 3-15 ppm in treated tubers when plants were sprayed 4-6 weeks before harvest with MH at the rate of 2-3 pounds per acre (concentration of the solution not specified).

Franklin and Thompson (34) found no significant difference in yields, specific gravity, cooked color ratings, and flavor, after MH sprays of 1250, 2500, and 5000 ppm applied just past full bloom. Tubers from treated plants were kept at 32° F., 40° F., 45° F., and 50° F. for 6 months.

Denisen (12) found no significant differences in specific gravity either before or after 5 months in common storage, or in reducing sugars as indicated by differences in chip quality from plants sprayed with 1500 ppm MH. The tubers contained 5.7 ppm MH residue.

Kennedy and Smith (45) applied MH to the foliage at rates of ¾, 1.5, and 3 lbs. of active agent in 100 gallons per acre at various intervals from 3-25 days before the signs of advanced senescence, or before vine killing operations. Weight losses other than those due to sprouting varied with different varieties, but there is no definite evidence that this was a varietal response. Apical dominance was destroyed, as shown by the larger number of active eyes; however, no true sprouts developed.

Salunkhe *et al.* (70) found that potatoes from MH treated plants showed a tendency toward higher specific gravity, and produced chips judged more acceptable than those made from controls. During storage at room temperatures the untreated tubers, which were lower in specific gravity, had a greater tendency to sprout.

The five authors last mentioned found similar favorable results on sprout inhibition by MH. Early applications (pre- and full-bloom) caused injury and yield reduction, but no injurious effect was observed with later applications.

Payne and Fults (65) reported that MH treatment applied about 6 weeks before harvest significantly increased reducing sugars content at harvest, whereas treatments about 10 weeks before harvest decreased reducing sugars in Red McClure potatoes. After 60 days' storage at approximately 40° F. the content of reducing sugars in potatoes that received early treatment was lower than in the controls, whereas in potatoes that received late application the content was higher than in the controls. However, these results, in the opinion of the authors are not great enough to have commercial value.

Oser (61) considered MH non-hazardous and non-irritating after 3 years' extensive toxicological studies. Three generations of rats fed exclusively on a diet containing 5 per cent sodium salt of MH showed no deviation from the normal.

Tate (76) reported the results of a 2 years' study of the effect of MH sodium salt on rats and dogs in relation to chronic oral toxicity. Rats were fed a diet containing 0.5-5 per cent active sodium salt of MH for 2 years; similarly dogs were fed 0.5-2 per cent for one year. No unfavorable effects were observed on the development or fertility, and an autopsy showed no evidence of tissue damage that was related to sodium MH.

Summary

Maleic hydrazide is very effective in prolonging dormancy of potato tubers and it has been extensively used in the U. S. Use of MH on growing plants offers definite advantages over general post-harvest treatment, because of rapid absorption, penetration, and translocation to desired plant organs. The choice of proper application time is very important since too early applications result in significantly reduced yields and in plant injury. Applications made too late in the season not only fail to reduce sprouting in storage, but may stimulate it. The chemical seems most effective if applied to the foliage when tubers are only partially grown, usually 2-7 weeks before harvest. MH is non-effective if used on harvested tubers.

Maleic hydrazide may be applied at a wide range of concentrations and of times of treatment, so that, within limits, any degree of dormancy may be induced. When a concentration of 2500 ppm is used, sprouting and shrivelling are delayed or completely eliminated for 7 months' to a year's storage at 50° F. There is no deterioration in quality and no reduction in yield of U.S. No. 1 potatoes. Apical dominance both on tubers and on individual tuber sprouts is destroyed, and the tubers cannot be used for seed purposes. Use of MH in prolonging dormancy of potatoes has permitted increase of storage temperature to 55° F. with no danger of sprouting. It has not been reported that MH causes breakdown of treated tubers in storage.

Some disagreement exists regarding the effect of MH on sugar content and consequent color and quality of chips. Lower reducing sugars content has been reported in MH-treated tubers stored at 45° F., and chips from treated tubers have been judged superior to chips from untreated tubers. Others have reported no significant difference in reducing sugars in MH-treated potatoes and controls, stored 6 months at 40° F. or 5 months in common storage. Also, MH has caused a significant increase in reducing

sugars content at harvest time and after 60 days of storage at approximately 40° F.

Three years' toxicological studies did not reveal any evidence of toxicity on dogs and rats which were fed a diet containing as much as 5 per cent active MH sodium salt. There is no evidence of MH accumulation in soil or as residues harmful to plants.

Methyl ester of alpha-Naphthalenacetic acid (MENA)

Guthrie (49) successfully retarded sprouting by enclosing 6 whole tubers in 5-lb. paper bags, each of which had previously been sprayed inside with acetone containing 480 mgs. of MENA. In further experiments (41) he inhibited sprouting of 6 whole tubers of Bliss Triumph for 108 days by storing the tubers in a container with filter paper impregnated with 2.5-22 mgs. of the ester. Ethylene chlorohydrin stimulated sprouting of tubers so treated.

Denny *et al.* (15) caused complete inhibition of sprouting for at least one year after harvest by using filter paper impregnated with about 10 gms. MENA per bushel of tubers and by storing at 50° F. in ventilated glass jars. Filter paper permeated with MENA still retained enough chemical after several months to be used successfully with a second crop of tubers. Continuous treatment gave best results, but no significant difference was observed between applying the chemical immediately after harvest and applying it 6 weeks later. No definite effect from the treatment was observed on sugar content of the tuber juice. When the amount of MENA was reduced to 2.5 gms. per bushel, and treated tubers were stored at 59° F., the inhibiting effect lasted only 6-8 months and moderate shrinkage occurred due to loss of moisture. At 64° F. and 73° F. (room temperature), more shrivelling occurred and the inhibition lasted 3-6 months.

Denny (14) completely inhibited sprouting of Irish Cobbler tubers for 7 months by adding paper towels impregnated with 2.5 gms. MENA per bushel shortly after harvest. These tubers germinated poorly when planted. The use of about 0.8 gms. of MENA per bushel of tubers was almost equally effective and germination of these tubers was 50 per cent. Successive treatment before planting with ethylene chlorhydrin alone, ethylene chlorhydrin plus Na thiocyanate, or thiourea, improved the germination but complete emergence was not obtained. An application of talcum powder containing about 0.6 gms. per bushel of MENA also gave good results at an initial temperature of 50°-59° F., and of approximately 73° F. during the last month. The author estimated that potato tubers in wooden bins exposed to MENA applied to paper towels at a rate of nearly 2.5 gms. per bushel of tubers, retained no more than 5 mgs. of methyl ester per kg. of tissue, and at least 4/5 of this amount was in the skin. Flesh from boiled or baked potatoes gave negative or very weak results on tests for methyl ester, indicating that the amount of chemical was less than 1 mg. per kg. of cooked flesh.

Stuivenberg and Velstra (75) used MENA on several potato varieties in cold storage cellars and in pits in a farmyard. Winter spraying with approximately 0.2 gms. and 0.5 gms. per bushel of tubers did not control sprouting successfully until March; 3 gms. per bushel did control sprouting, but this amount was too expensive. However, spring spraying, at the time potatoes first showed sprouting, with 0.4 gm. per bushel of tubers

successfully inhibited sprouting until July. Treated potatoes cooked well, maintained their quality, and were harmless to the consumers.

Thomas and Riker (77) reported that applications of MENA at 0.9 gm. per bushel as a spray in dilute alcohol or lanolin emulsion, or as dust in talc or walnut-shell flour, or impregnated in shredded paper, were effective on Chippewa , Cobbler, Russet Burbank, Russet Rural, Red Warba and Triumph varieties. Potatoes treated in January and February were kept 2-4 months at 70° F.; the tubers lost some water but were still marketable at the end of the storage period, whereas the controls were worthless. The treatment lost its effect with time. Four to six weeks after treatment, Cobbler tubers developed hard knobs, usually in the bud area. The same authors (78) inhibited sprouting almost completely for 70 days at 70° F. in Chippewa, Cobbler, Russet Rural, and Triumph varieties with an application of 0.4 per cent MENA dust. The treated Cobbler tubers again developed hard knobs, mainly in the bud areas. Each variety lost less weight than the control, but Chippewa showed the least response to the sprout inhibitor. The authors suggested that the best time to apply the chemical is before the tubers break dormancy and begin to sprout.

Denny (13) emphasized that prevention of sprouting is not the whole answer, since storage temperature is important in determining culinary quality. The results of his experiment showed that tubers treated with 3.7 gms. per bushel of MENA impregnated in shredded paper, or 1.8 gms. MENA per bushel in talc or soil garden, could be stored from the end of October to the beginning of April at 54° F. without sprouting and without undue shrinkage from loss of moisture. Sprouting was nearly inhibited by 1.8 gms. MENA per bushel (paper treatment), but at 0.9 gms. per bushel considerable sprouting occurred. Tubers so treated and stored showed few traces of reducing sugars and furnished potato chips of good color.

Smith (72) discussed several methods of applying MENA, suggesting the dust or the paper treatment for small lots of potatoes. Ten gms. of the chemical can be mixed with one lb. of talc, walnut-shell flour or other inert dust and applied evenly to 10-11 bushels of potatoes, or 6 lbs. of paper impregnated with the 100 gms. of the methyl ester are sufficient for 100 bushels of potatoes. For larger amounts, the MENA was diluted with methyl alcohol 1:1 and the mixture atomized on the tubers during loading of the bins. Escape of fumes should be prevented. For aerosol treatments, one part of MENA may be mixed with 9 parts of methyl chloride. Potatoes treated with MENA remained dormant or with short sprouts 4-5 months at 50°-55° F. or at higher temperature for shorter periods. The treatment did not cause rotting on large lots of the varieties Sebago, Katahdin, Sequoia, Erlaine No. 2, Smooth Rural, and Russet Rural.

Daines and Campbell (11) successfully inhibited sprouting during 4 months at 57°-70° F. in Katahdin potatoes treated shortly after harvest with a dust application of ⅔-1⅓ gms. of MENA per bushel. Treated potatoes germinated poorly even 2 months after planting and sprouts were abnormal. When potatoes were treated after the dormant period, proliferation and blackening of the affected tissues occurred.

Luckwill (49) using MENA in shredded newspaper, 2.7 gms. per

bushel, reduced sprouting to a very low value in Majestic variety. Treated tubers were kept from November to June in a storage barn protected from the winter frost and the summer heat. MENA mixed with dry soil containing a high clay fraction did not control sprouting.

Luckwill (50) suppressed sprouting for nearly 7 months in Majestic potatoes treated with 2.7 gms. MENA per bushel, as dust application at the beginning of November. Controls started to sprout in the middle of April, and at the end of the experiment the loss in weight was 24 per cent, whereas the treated tubers lost less than 10 per cent. The same author (51) inhibited sprouting for 9-10 months after harvest by treating with paper strips sprayed with MENA dissolved in methanol or acetone.

Pujals *et al.* (66) treated Triumph and Cobbler seed potatoes with MENA, 0.54 gms. per bushels in talc and stored the tubers at 50°-55° F. and 68°-82° F. for nearly 100 days. Just before planting the tubers were treated with 40 per cent ethylene chlorohydrin solution at the rate of 1.3 cc. per cubic decimeter of the container for 24 hours. Tubers first chemically treated to inhibit sprouting and later treated with ethylene chlorohydrin to break dormancy, produced lower yields than tubers treated for breaking dormancy only. The former had smaller and fewer sprouts at planting time and did not recover completely from the inhibiting treatment. This indicates, however, that ethylene chlorohydrin is able to counteract partially the effect of the sprout inhibitor and improved methods of its use could possibly be devised.

Smith and Scudder (74) reported that 500,000 bushels of potatoes were treated with MENA on Long Island. The dust treatment was considered most practical, and potato growers received a price premium late in the season because of the good appearance of the tubers.

Smith *et al* (73) planted Sebago potatoes on May 15 and applied MENA on July 14; July 14 and 28; July 14, 28 and August 11; July 14, 28, August 11 and 25, at a concentration of 10,000 ppm first application and 4000 ppm afterward, at a rate of 55-110 gallons per acre. The treatment caused severe rolling and injury to the sprayed leaves and scab-like injury to the tubers. Yield of U.S. No. 1 tubers and total yield were reduced and the specific gravity lowered. Treated plants had few flowers, while untreated ones flowered abundantly.

Ellison and Smith (23) determined the effect of applying MENA to plants in the field at concentrations of 3500 and 7000 ppm, in an aqueous spray of 300 gallons per acre. Three applications were made (July 17, August 19, and September 11) to separate plots. The potatoes were harvested in November and kept 70 days at 50° F. The July application reduced both yield and specific gravity by injuring the plants, although sprouting in storage was controlled most effectively. The August and September applications did not affect yield. With the August application, tubers sprouted only half as much as did the controls, but no inhibition was associated with the September application. Treated tubers contained significantly less reducing sugars than the controls after storage at 40° F. for 6 months, the earlier the treatment the lower the concentration. When treated tubers were planted to determine their value as seed, no significant difference was found between yields from treated and control tubers. There was no significant difference between 3500 and 7000 ppm of MENA in the sprays.

About 200 bushels of Katahdin potatoes were treated by Blood and Kardos (3) at the end of the rest period during the last week of March, with 42 gms. of 2.2 per cent MENA per bushel. Tubers were still salable at the end of July and the loss of weight was 3.17 per cent.

Luckwill (52) observed a differential varietal response to sprout inhibitors, the same variety being more sensitive to one chemical than to another. In his experiments MENA stimulated respiratory activity in stored tubers and the consequent loss of food diminished the gains due to sprout inhibition and reduced water loss.

Orman (60) and Claridge (9) from Australia and New Zealand, respectively, reported favorable results with MENA.

Gandarillas and Nylund (37) dusted Cobbler seed potatoes with MENA at a rate of 0.54 gms. per bushel on October 8, November 8, December 7, and January 8. Tubers were kept at 36°-40° F. and 50°-54° F. MENA was most effective when applied as late as possible before the end of the rest period. MENA-dusted tubers were treated with ethylene chlorohydrin on March 10, April 8, and May 2, and all samples were planted in the field on May 8. The following results were reported from the treatment of seed tubers with MENA:

(1) Emergence delayed 11-16 days; (2) number of stems per plant reduced about 5 per cent; (3) stand of plants reduced; and (4) yield reduced about 21 per cent.

When ethylene chlorohydrin was applied to MENA-treated tubers six days before planting, the results were as follows:

(1) Emergence delayed 3 days; (2) number of stems per plant reduced about 3 per cent; (3) stand of plants equal to that of plants from untreated; and (4) yields varied.

A dust application of 2.7 gms. MENA per bushel was considered practical, cheap, and effective in sprout inhibition of potatoes by Rakitin and Trojan (67).

Montenegro (58) reported satisfactory inhibition of sprouting for 2 and a half months by treating tubers with 37.8 gms. of 1 per cent MENA per bushel in talc, 2 months after harvest.

Ellison and Smith (24) dusted non-dormant Sebago potatoes on April 17 with 1 gm. MENA per bushel. Treated potatoes were kept in paper bags at 50° F. until June 28 when 1.5 gms. of sprouts per tuber were observed. The controls had 10.8 gms. of sprouts per tuber.

Methyl ester of Naphthaleneacetic acid should be applied before tubers break dormancy and sprout. In fact, MENA gave poor results on Chippewa potatoes with sprouts 0.5-1 inch long, when desprouted, treated, and stored 40 days at 58° F. (Bradley and Dean, 4).

Edwards (20) found best results with a dust application of 2 gms. of MENA per bushel applied just before the end of the rest period, using Sebago and Katahdin varieties. Katahdin's variety response was better than Sebago's. In the latter dry rot was observed, especially with applications immediately after harvest. Sprouting in both varieties was controlled but not completely inhibited, and loss of weight was reduced.

Sprouting was completely inhibited by Marth and Schultz (55) when 1 gm. of shredded paper impregnated with MENA (rate 1 gm. per bushel) was enclosed in cellophane bags containing 6 lbs. of tubers (Katahdin and Sebago varieties). Bags were sealed and kept 112 days at 68°-75° F.

Sprouting was almost completely inhibited after 144 days in common storage by placing 30 gms. of shredded paper impregnated with MENA (rate 3.6 gms. per bushel) in the paper bags. The authors suggested the use of the chemical to prevent sprouting and subsequent late blight infection on potato waste piles.

Wagner *et al.* (79) dusted Russet Burbank potatoes with MENA at a rate of about 0.9 gms. per bushel, and stored the tubers at 40° F., 72° F., and 90° F. After 17 weeks at 40° F. no sprouts were observed on treated tubers, which were firm and unshrivelled. About one half of the untreated tubers developed sprouts 1/16 inch long or less, with some evidence of slight dehydration. At 90° F. no difference was observed between the treated tubers and the controls, indicating that the high temperature was the inhibiting factor. At 72° F. after 17 weeks the results indicated that treatment with MENA would greatly reduce sprouting and losses from dehydration.

Under field test conditions with 18,000 lbs. of potatoes, no advantage followed pre-storage treatment or after 3 months storage, since no sprouting occurred during 7 months at 40° F. All lots sprouted when, after 6 months, potatoes were transferred for 2 months to a root cellar with a temperature of 56° F. or were held 1 month in a root cellar and 1 month in an outside shed. Sprouting was more rapid with increasing outside temperature. The authors concluded that treatment must be accurate to be effective since ventilation tends to dissipate the inhibitor and the inhibitor is neutralized by the presence of soil on unwashed potatoes.

Ellison and Cunningham (25) found that Fusarium dry rot infection is more likely to occur in stored potatoes treated with a MENA compound than in controls kept under the same conditions. Sprouting was satisfactorily controlled in Green Mountain potatoes treated with MENA at 1 gm. per bushel and kept at 60°-70° F. the first month and at 50°-60° F. about 4 months, with a relative humidity usually 80-90 per cent. After artificial inoculation with *Fusarium sambucinum* f.6, the per cent of infection was significantly higher in MENA-treated tubers than in the control. In Katahdin potatoes treated with MENA 1 gm. per bushel and stored 3-4 weeks at 50°-60° F. and 3 months at 35°-45° F. with an average relative humidity of 80 per cent, sprouting was almost completely controlled, but again the per cent of Fusarium infected tubers was higher than in the controls.

Cunningham (10) found that sprout inhibitors containing MENA caused irregular suberization of wounds in potato tubers, formation of wound cork was delayed, and in some cases inhibited. This inhibition created favorable conditions for the penetration of *Fusarium sambucinum* f.6, agent of dry rot in storage. Amounts of MENA used were not specified but exceeded those recommended by the manufacturers. The author emphasizes that an uneven dust application results in accumulation of the chemical on certain parts of the tuber resulting in less wound cork formation here than on parts receiving a smaller dosage.

Triumph, Pontiac, and Red Pontiac potatoes commercially stored several months at a temperature gradually lowered and kept at 36°-40° F. were dipped in or brushed with solutions containing the MENA (Findlen, 33). After one month at 59° F. sprouting was well controlled, the Triumph potatoes showing less sprout growth than Pontiac. The author

found MENA at 0.46 gm. per bushel in an aqueous wax emulsion more effective than in water. This concentration was reached by an emulsion of 2.1 per cent MENA at a rate of 1 gallon per 10,000 lbs. of potatoes. The treatment was most effective on unsprouted tubers but was also satisfactory on desprouted ones.

Finch and Hartzell (*32*) studied the effect of a diet containing MENA on mice. The methyl ester present in treated potatoes was estimated at approximately 5 mgs. per kg. The mice exhibited normal weight curves when fed a diet of treated potatoes, and no deviation or change was observed when MENA in the diet was increased to 90 times the concentration believed to be present in ordinary treated potatoes. In 3 generations of litters born of females continuously fed the highest concentration (the 90 times dose) no significant difference from control mice was observed in number of young born, per cent reared, or rate of growth during the first 21 days after birth.

Summary

Of the various auxins that have been used for prolonging dormancy, the methyl ester of alpha-Naphthaleneacetic acid has gained the widest use in the United States. It has also been used in South America, Australia, New Zealand, Europe and Russia. MENA has been used successfully on potatoes as a sprout inhibitor; it is fairly volatile at room temperature (77°-82° F.) and acts efficiently in vapor form. It seems that conditions in storage and handling practices can reduce its effectiveness, since unfavorable results were obtained when MENA was mixed with a dry soil containing a high clay fraction, or when applied to unwashed potatoes, or used in storages with excessive ventilation. However, the chemical was successfully incorporated in talc or garden soil and applied as a dust.

In 1947 it was used on Long Island on a commercial scale, and potato growers were completely satisfied with its performance.

Since the chemical has no observed effect on sugar content of tubers, potatoes could be stored at a temperature sufficiently high (55° F.) to maintain reducing sugars at the low value required to produce potato chips of good color but not high enough to promote sprouting.

Dust and paper treatments are suggested for lots of potatoes up to 1,000 bushels, and paint spray gun or aerosol treatments for larger amounts. Care must be taken that none of the chemical gets into the eyes or nasal passages or comes in contact with the skin of operators, since it may cause severe irritation.

The best time of application seems to be as late as possible before tubers break their dormancy and begin to sprout. Early applications in the field caused foliage injury and reduced both yield and quality of the tubers. Late applications did not cause injury but did not control sprouting.

Tubers treated after harvest proved inferior to untreated ones when used for seed. Treatment with ethylene chlorhydrin 6 days before planting did not counteract completely MENA's depressing effect on rate of growth and number of sprouts. Final stand and yields, however, were not greatly different from those of untreated tubers. Until better methods of breaking chemically-induced dormancy are devised, treated tubers should not be used for planting purposes.

Varietal response has been observed. Cobbler potatoes developed hard knobs 4-6 weeks after treatment, whereas Chippewa potatoes showed less response. There is evidence that MENA-treated potatoes are more susceptible to attack of Fusarium dry rot infection due to the detrimental effect on wound cork formation. No evidence of toxicity was observed on mice that were fed a diet of MENA-treated potatoes, though the chemical's concentration was increased as much as 90 times the amount believed to be present in treated potatoes. It was estimated that a residue of 5 mgs. per Kg. of tissue remains after treatment with 2.5 gms. per bushel, and less than 1 mg. per kg. of cooked flesh.

Terpineol and alpha-Chloronaphthalene

Emilsson (28) found terpineol and alpha-Chloronaphthalene more efficient than MENA in sprouting inhibition.

Edwards (21) used terpineol and alpha-Chloronaphthalene at the rate of 2 gms. per bushel on Sebago potatoes. Treated tubers were inferior to untreated controls in respect to sprouting and per cent of marketable tubers.

Findlen (33) applied alpha-terpineol in an aqueous wax at 2.7-5.4 gms. per bushel. Sprouting was somewhat reduced, but not so effectively as with MENA in an aqueous wax emulsion at 0.46 gms. per bushel. Alpha-Chloronaphthalene in an aqueous wax at 2.7 gms. per bushel was very effective but injured the tubers. Increased concentrations killed the buds completely and caused necrotic spots at the lenticels.

Summary

The promising results reported at first with terpineol and alpha-Chloronaphthalene were not confirmed by further experiments so that definite conclusions are lacking.

2,3,5,6-Tetrachloronitrobenzene (TCNB) and Related Compounds

Brown (5) suggested use of chlorinated nitrobenzenes for prolonging the storage life of potatoes. The best results were obtained with 5 per cent TCNB. Nearly all treated tubers that overwintered in clamps covered with straw and soil had not sprouted at the end of May. When used for seed, treated tubers must be handled with care since they sprout at one or two eyes only. If care is taken in planting, however, yields are slightly higher than from untreated controls. Untreated controls are more susceptible to frost injury and to attack from fungi or viruses and must be desprouted before planting.

Luckwill (52) impregnated confetti paper with TCNB at a rate of 0.54, 1.35, 2.7 gms. per bushel and distributed it among potatoes in wooden fruit boxes lined with grease proof paper. A varietal response was observed since TCNB was very effective in inhibiting sprouting in Arran Banner variety, but relatively ineffective on Kerr's Pink. In England TCNB had the advantage of being much cheaper than MENA.

A dust containing 3 per cent of TCNB was found useful in preventing sprouting of Bintjie potatoes that overwintered in clamps made after harvest. It was applied at the rate of approximately 121 gms. per bushel and results varied a little from place to place. It was important to cover the clamp with soil to prevent loss of vapor. Germination of treated tubers

was not affected, and partial control of *Fusarium spp.* was noted (Mooi, 59).

Emilsson *et al.* (29) obtained satisfactory sprout inhibition with TCB at 2 gms. per bushel. In most cases there was less rot loss from treated than from untreated tubers. Slight losses of weight, increased starch content, and unchanged cooking quality were associated with the treatment.

A dust containing TCNB applied to potatoes at harvest time in November, at approximately 125 gms. per bushel, kept potatoes firm and dry after 5 months of storage, prevented rots caused by *Fusarium coeruleum*, and inhibited excessive sprouts. Treated potatoes were planted in March and gave better growth and yield than untreated seed, 10 and 9.2 tons per acre respectively (Anon., 2). The best results were obtained when potatoes were treated at harvest time or within 24 hours, and care taken to avoid free air circulation for at least 4-6 weeks. The potatoes should be aired at least one month before planting.

Glasscock (38) obtained no successful sprout inhibition of potato in clamps treated with a dust containing 3 per cent of TCNB on China clay filler in autumn, with a chimney left at the top for ventilation.

Downie (17, 18) found that a 3 per cent TCNB compound dusted on tubers immediately after harvest at approximately 122 gms. per bushel prevented sprouting and that tubers were firm and attractive after 6 months, but germination was depressed. A varietal response was observed in these experiments, since sprouting occurred after 3 months in all varieties except Snowflake, a late variety. Weight losses were considerably reduced by TCNB on the Early Carman, Katahdin, and Snowflake varieties. The efficiency of the treatment seems to be associated with the length of dormant period. After 7 months, sprout inhibition in Snowflake variety was still very evident. The use of sprout inhibitors in Victoria, Australia, appears suitable to the author only under special conditions and the Snowflake is the recommended variety.

Emilsson *et al.* (30) found that 3.3 gms. of TCNB dust per bushel inhibited sprouting very effectively, whereas loss of weight and loss through diseases were significantly decreased. No significant change in taste was noted and treated potatoes showed less tendency to darken after boiling.

Brown and Mellor (6) found that several chlorinated nitrobenzenes, 2,4,5-, 2,4,6-, and 3,4,5-Cl_3-$C_6H_2NO_2$, prevented potatoes from sprouting. The amount of active substance employed was about 2.3 gms. per bushel.

Ellison (22) dusted Green Mountain potatoes with 2.7 gms. of TCNB per bushel at the time of loading the bins. Treated tubers were kept in common storage at a temperature of 45°-50° F. in the fall and 35°-40° F. in the midwinter and at a relative humidity of nearly 90 per cent. After approximately 2 and one-half months sprouting was still inhibited. The chemical was not able to inhibit sprouting after 55 days when treated tubers were exposed to free air. There was considerable sprouting in the top layer and around the edges of treated bins, but the free air was not effective 3 inches inside the bins. TCNB is thus very effective for treating large lots, *i.e.*, bins of 10-25 bushels capacity, but less effective for small quantities since practically all tubers are exposed to the air.

Ellison and Cunningham (25) found that Green Mountain potatoes treated with TCNB at 2.7 gms. per bushel were in good condition after

5 months. The temperature was 60°-70° F. in the first month and 50°-60° F. afterwards with relative humidity of approximately 80-90 per cent. The per cent of infection following artificial inoculation with *Fusarium sambucinum* f.6 was a little lower than the uninoculated control. Similar results were obtained with the Katahdin variety.

Cunningham (10) concluded that TCNB used as liquid and dust treatment in amounts exceeding the dosage recommended by the manufacturers caused at the beginning an irregular wound cork formation, but a continuous layer was successively formed, so that damage due to dry rot was not greater than in untreated tubers.

Wilson and Dawson (81) treated potatoes with a dust containing 3 per cent of TCNB at the rate of 125 gms. per bushel to determine TCNB residues. When the distribution was not uniform, individual tubers from the same clamp showed a variation of 0.1-53 ppm after 3-4 months. With a more careful distribution, results were somewhat more uniform with 0.8-14 ppm. With commercial methods of handling potatoes before and after storage, and transportation to the retailer, surface residues of ACNB after 4-5 months were estimated at approximately 2 ppm. According to this figure a man eating 12 ounces daily of unpeeled, unwashed potatoes, would ingest approximately 1/10,000 of the daily dose indicated by Abrams *et al.* (1) as non-toxic to pigs. With a limited number of analyses of peeled, treated potatoes, no traces of TCNB were found.

Brown and Reavill (7) found that the repressive effect of TCNB on growth rate disappeared when tubers were removed to fresh air. Airing for about 7 weeks is required for the dusted tubers to become equal in yielding capacity to the sprouted control. A warm darkened room provides the best conditions for "rejuvenation."

In a previously mentioned report (Anon., 2), TCNB is considered of such a low toxicity level as to be defined non-poisonous and thus suitable for human consumption and stock feeding. No toxic effect was found in mice, rats or pigs. Inhalation experiments with rats showed no harmful effect, and eye instillation in rabbits showed no reaction, but some TCNB caused severe congestion in the eye of one worker for a few days, however, no ill effect followed.

Abrams *et al.* (1), after extensive experiments with pigs, concluded that a daily intake of 7.1 gms. of TCNB added to the food mixture immediately before feeding, retarded growth up to 6-7 months, but the final live weight at approximately 10 months of age was not significantly less than that of the controls. Since this quantity is 10 times higher than that used on potatoes, pigs fed with TCNB-treated potatoes should not show toxic responses.

Feeding tests on mice and rats performed by Buttle and Dyer (8) showed that growth inhibition and death followed only the highest amount of daily intake. Inhalation tests with rats 3 times a day for 10 days or instillation into the eyes of rabbits each day for one week, did not show any effect of the dust or symptoms of irritation.

Summary

2,3,5,6-Tetrachloronitrobenzene first described in 1868, was used as a fungicidal ingredient to control the dry rot in clamped potatoes caused by *Fusarium coeruleum*. Its ability to retard or suppress sprouting was

then noted, and since then chlorinated nitrobenzenes have been used successfully to prevent sprouting of potatoes, especially in England, Sweden and Australia.

The chemical should be applied immediately after harvest or within 24 hours, to prevent sprouting and maintain firm, attractive tubers. TCNB is ineffective when treated tubers are exposed to fresh or circulating air, as is demonstrated by excessive sprouting at the tops of treated bins. Airtight rooms or containers are needed to store small quantities of treated potatoes. TCNB has not been used as a pre-harvest treatment.

Germination is depressed by TCNB, but the compound is slowly volatile and is expected to lose its inhibiting effect after 6-8 months. Its volatility could explain the great variation in amounts used by investigators in controlling sprouting. Airing dusted tubers 7 weeks before planting seemed to be sufficient to break chemically induced dormancy, however, treated tubers used for seed sprouted only at one or two eyes which necessitates careful handling.

So far as storage diseases are concerned, TCNB is considered more reliable than MENA as a sprout inhibitor, especially because Fusarium dry rot is more prevalent in stored potatoes treated with MENA than in TCNB-treated tubers or in the controls.

The chemical seems effective only on late varieties, and its efficiency is associated with the length of the dormant period. No toxic effect was observed on mice, rats or pigs. The effect of TCNB on reducing sugars content of treated tubers has not been reported.

2,4-Dichlorophenoxyacetic acid (2,4-D), 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) and Related Compounds.

Kenneth (46) reported that an after harvest treatment of methyl ester of 2,4-D at 2 per cent and 4 per cent concentrations both in dust and in wax emulsion caused rapid breakdown of the tubers, in Irish Cobbler and Katahdin varieties, and abnormal growth around the eyes, although it was efficient in inhibiting sprouting. Treatment with dust containing the sodium salt of 2,4-D at 0.5-1 per cent showed considerable variation, according to variety and temperature of storage, in sprouts development, in weight loss and in response to concentration.

Ammonium 2,4,5-T sprays, applied in field and greenhouse to plants one foot high, at a concentration of 0.1 gms. per square yard in 10-50 mls. of aqueous solution, drastically reduced yield and plant growth. Tubers were reduced in size and had a scab-like injury which was largely superficial (Ennis *et al.*, 31). Ammonium 2,4-D caused epinastic responses soon after treatment but the plants recovered after a few days. 2,4-D, either in aqueous or oil sprays, did not affect the quality of the tubers but reduced yield significantly.

Luckwill (50) found that methyl ester of 2,4-D applied in autumn was ineffective in preventing sprouting.

Smith *et al.* (73) found that 4 applications of sodium 2,4-D, 10 ppm at several stages of growth on Sebago variety, had no visible effect on plant growth, and that, after 11 weeks at 41° F., tuber-yield, specific gravity, and reducing sugars content, were not affected. After 3 months' storage at 50° F. the tubers had significantly less sprout growth than had untreated tubers.

Fults and Schaal (35) found that the sodium salts of 2,4-D and its

butyl ester, applied as side dressing at 20 lbs. per acre when tubers were ⅓ grown, did not cause apparent injury or reduction in yield. However, an increase in the red skin color of Bliss Triumph and Red McClure potatoes occurred, though no change in color or flavor of the flesh was noted.

Ellison and Smith (24) used aqueous sprays of sodium 2,4,5-T on Sebago variety at 150 gallons per acre, 67, 89, and 108 days after planting, and at several concentrations. Early application of 300 ppm gave the best sprout control after storage for 4 months at 50° F. but the tubers were injured. A concentration of 50 ppm did not cause injury at any time of application. Houma potatoes treated in the spring in open baskets in storage with isopropyl ester if 2,4,5-T at 0.9 gms. per bushel sprouted significantly less than the controls but the treatment was inferior to MENA.

Wood and Ennis (84) observed that tubers from Irish Cobbler plants sprayed with butyl 2,4,5-T, 5, 9, and 11 weeks after planting, were more susceptible to *Streptomyces scabies* attack and the plants showed injury. Treated tubers had fewer layers of wound cork and fewer starch grains than the untreated lots. Treated tubers used as seed failed to sprout or did very poorly.

Marshall and Smith (53) sprayed Houma potatoes with sodium salt of 2,4,5-T at 100 gallons per acre at full bloom, and 2 to 4 weeks later at concentrations of 25-200 ppm. No tuber injury and no reduction in yield was observed, but sprouting was not completely prevented (50 per cent of the control).

Methyl and isopropyl esters of 2,4,5-T, as a 2.2 per cent dust suspended in a solution of 3 parts of ethyl alcohol and 1 part of water (5000 ppm actual chemical), prevented sprouting almost completely after 100 days at 50° F. The authors suggested that 2,4,5-T could be effectively used as a sprout inhibitor with improved methods of application.

Fults *et al.* (36) increased red skin color of Red McClure potatoes by side dressing or soil-spray at the base of the plant using sodium salt of 2,4-D at 1, 5, and 20 lbs. per acre. Yields were not significantly affected. Red skin color was also increased by 2 sprays, pre- and post-bloom, at 0.26, 0.52, 1.04, and 1.52 lbs. per acre (applied in 100 gallons of water) without yield reduction. The lowest rate was almost as effective as the highest. However, the red pigments present in young tubers are not stabilized by 2,4-D, since the treated tubers lost color when they reached maturity.

Marth and Schultz (55) found that the ethyl ester of 2,4,5-T, 0.3 gms. in 30 gms. of shredded paper per 5 lbs. of potatoes, almost completely prevented sprouting after 144 days in common storage (tubers sealed in paper bags). The same amounts of methyl, butyl and amyl esters of 2,4-D were not satisfactory. In field experiments, non-dormant potatoes were sprayed with isopropyl and butyl esters of 2,4,5-T as an aqueous suspension at a 0.25 per cent concentration with 0.25 per cent machine oil (SAE 20) added and emulsified with 1 per cent Emulphor AG (oil soluble). Potatoes were piled to depths of 8-14 inches. Sprouting was prevented without injuring the tubers sufficiently to cause rotting. Sprouts present at the beginning of the treatment were completely checked.

Payne *et al.* (64) were able to increase the red skin color of Red McClure potatoes by applying ½-1 lb. per acre of sodium salt of 2,4-D

as a basal plant spray when tubers were ¼ of an inch in diameter. The intensified red skin color persisted throughout 5-6 months of storage at approximately 40° F., but the treated as well as the untreated potatoes lost color. Treated potatoes sprouted significantly less than controls, but sprout inhibition was not complete. When treated and untreated tubers were desprouted and planted, no significant differences were observed in stand, number of stems per plant, or yield.

Summary

2,4-Dichlorophenoxyacetic acid, 2,4,5-Trichlorophenoxyacetic acid, and related compounds have been used in the United States and England following different methods of application: to the foliage at several stages of growth or after harvest. Reports on their toxicity are lacking.

As a sprout inhibitor 2,4-D is not completely satisfactory. Methyl, butyl, and amyl esters of 2,4-D were ineffective and caused injury to the tubers. The sodium salt of 2,4-D showed variable effects and achieved partial control of sprouting without injuring the plants or reducing yields. Sodium and amonium salts of 2,4-D increased the intensity of color of certain red skinned varieties such as Bliss Triumph and Red McClure, without affecting the yield. Since a deep red color is highly desirable in marketing, this observation could have practical application and deserves more attention. One paper mentions that the sodium salt of 2,4-D had no effect on the reducing sugars content of treated tubers.

Sodium and amonnium salts of 2,4,5-T controlled sprouting but injured the tubers. Lower concentrations did not cause injury but sprout inhibition was less successful. Butyl 2,4,5-T made tubers more susceptible to attack of *Streptomyces scabies*, and injured the plants. Methyl, isopropyl, and butyl esters of 2,4,5-T appeared promising as sprout inhibitors.

The effectiveness of 2,4,5-T, 2,4-D, and related compounds to inhibit sprouts is inversely related to the ability of treated tubers to germinate when used as seed.

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DETECTION OF POTATO LEAF ROLL BY PAPER CHROMATOGRAPHY AND ELECTROPHORESIS[1]

CHARLES W. MCANELLY, MERLE G. PAYNE, AND JESS L. FULTS[2]

In certifying potatoes for seed it would be convenient and valuable to have a simple chemical test that would show the presence or absence of virus disease. The standard greenhouse indexing procedure and the practice of growing sample lots of northern-grown seed in the south during the winter have the disadvantage of delaying critical information until so late that it often loses much of its value. A chemical method of detection which was at least as dependable as the standard practice might be cheaper and faster. Since leaf-roll is one of the most commercially important viruses in the potato certification program in this area it was selected for exploration and study.

REVIEW OF LITERATURE

A search of the literature for pertinent papers has indicated that some of the most significant information was published by Reed Gray in 1952 (3). Included in the paper was a review of pertinent papers published between 1943 and 1952. Of particular interest are the papers of Wildman, Cheo and Bonner in 1949 and of Wildman and Bonner in 1950. No pertinent papers of significance have been found published between 1951 and 1955. Gray, in closely controlled experiments, showed that tobacco mosaic virus could be readily detected in the proteins of infected tobacco plants by either electrophoresis of proteins on filter paper or by simple one-dimensional paper chromatography of the proteins in 40 per cent alcohol. In either technique juice samples from leaves were used as a starting point. Potato Y virus and cucumber mosaic in tobacco were also detected by these techniques but with more difficulty. The tobacco mosaic virus protein was distinguishable from both the potato Y virus and the cucumber mosaic virus by their different rates of migration on the electrophorograms.

MATERIALS AND METHODS

Russet Burbank tubers from a field known to contain about 10 per cent leaf roll were obtained in the fall of 1953. These tubers were indexed in the greenhouse at Fort Collins, Colorado, during the winter of 1953-1954. One hundred tubers harvested from plants that appeared to be healthy and one hundred tubers from plants showing leaf roll symptoms were cut and planted in separate field plots, west of Fort Collins, Colorado, in the summer of 1954. Sixty tubers from each of these plots were randomly selected, at harvest, in the fall of 1954.

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[2]Assistant Horticulturist, Department of Horticulture; Associate Chemist, Department of Chemistry; and Botanist, Department of Botany and Plant Pathology, respectively, Agricultural Experiment Station, Colorado A & M College, Fort Collins, Colo.

In the winter of 1954-55 one seed-piece from each of the sixty healthy and sixty leaf roll tubers was used for a second indexing in the greenhouse. The remaining eyes from each tuber were removed with a cork borer to a depth of one-fourth inch. These were put in a cellophane bag, numbered and quick frozen. Juices from these eyes obtained after thawing were used for two-dimensional paper chromatography described later.

Six healthy and six leaf roll plants were selected at random from the second greenhouse indexing. The tubers from these plants were collected; the eyes of one tuber from each plant were then removed and quick frozen as before. For chemical tests, the eyes were thawed and squeezed to obtain the juice samples. This was then lyophilyzed to one-fifth its original volume and one-dimensional chromatograms and electrophorograms were run as described below.

Paper Electrophoresis

A Wieland type of electrophoretic instrument modified by Grassmann and Hannig (4, 5) was used to produce zone-electrophorograms (Figure 1). The pH of the cacodylic buffer,[3] which served as the electrophoretic electrolyte, was adjusted to 6.93, just above the isoelectric point of the potato protein, so that the protein fraction moved anodically. The ionic strength was 0.1.

A five-microliter aliquot of a juice sample concentrated 5 to 1 was pipetted near one end of a buffer-dampened filter paper strip (Whatman No. 1), one and one-fourth inches wide. The instrument was run six hours at 300 volts and five milliamperes, after which the paper strips were taken out and put immediately, (that is, without drying) into a dye bath of amido black 10B[4] (Farbenfabriken, Bayer, Leverkusen, Germany) for ten minutes. Upon coming out of this bath, the strips were dyed a dark color. Three ten-minute baths of five per cent phenol were

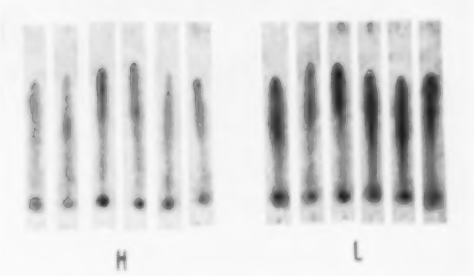

Figure 1.—Electrophorograms from the tuber juice of six healthy and six leaf roll progeny of the second year indexing of Russet Burbank potatoes.

[3]Cacodylic Buffer:
4.68 gms. of salt
4.28 gms of sodium cacodylate
0.46 gms of cacodylic acid
Dissolved in enough distilled water to make one liter

used to destain the strips of paper, followed by fixation in 10 per cent concentrated glacial acetic acid in absolute methanol. The strips were then dried (Figure 1), leaving the protein zones with a dark blue color.

The relative amount of proteins in the tuber juices was measured by passing the dried electrophorograms through a densitometer (Welch and Company Densichron) at 3 mm intervals followed by plotting the optical density data on graph paper and measuring areas under the curves with a planimeter. Since the amount of amido black 10B adsorbed is directly proportional to the amount of protein on the paper (4), the optical density curves were used to compare healthy and diseased tubers. Figure 2A illustrates typical results.

Paper Chromatography

Ascending one-dimensional paper chromatography was used, as described by Williams and Kirby (6). Small sheets (20 x 20 cm) of Whatman No. 1 filter paper were used. The solvent was forty per cent ethyl alcohol. Ten microliters of one-fifth concentrated juice were placed

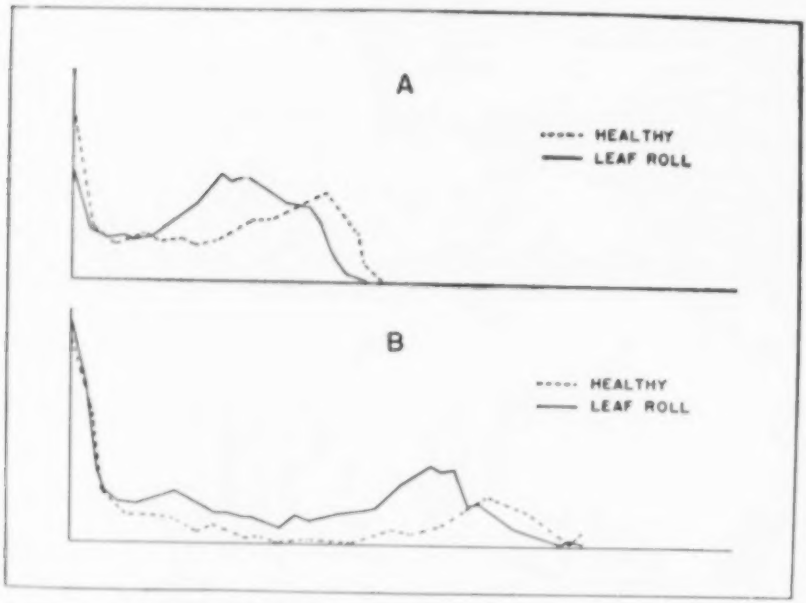

Figure 2A.—Typical optical density curves from electrophorograms showing the protein fractions of healthy and leaf roll Russet Burbank potato juice. B.—Typical optical density curves from one-dimensional chromatograms showing the protein fractions of healthy and leaf roll Russet Burbank potato juice.

[4]Dye Bath
2.5 gms. of amido black 10B
450.0 mls. of acetone — free absolute methanol
50.0 mls. of glacial acetic acid

on the paper and dried, chromatographed in a closed container at constant temperature. After the solvent had ascended the paper, the paper was removed and put immediately, that is, without drying, into a dye bath of amido black 10B, fixed and destained as described for the electrophorograms. Figure 3 illustrates the typical results.

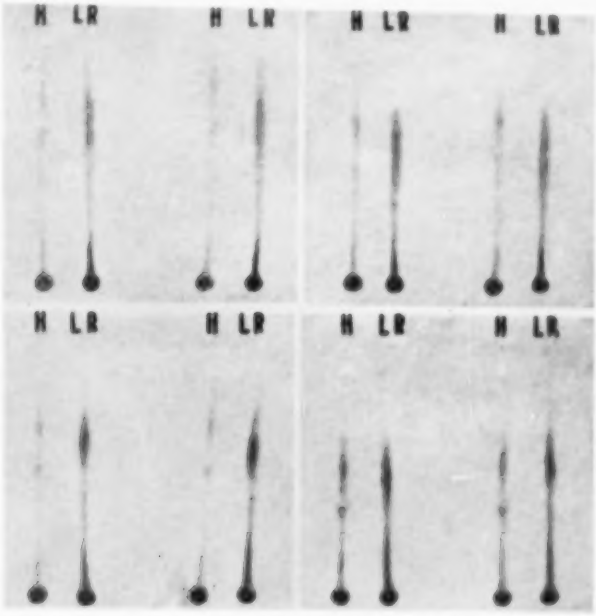

FIGURE 3.—One-dimensional chromatograms from the tuber juice of healthy and leaf roll progeny of the second year indexing of Russet Burbank potatoes.

Two dimensional paper chromatography was carried out according to the techniques described by Franklin and Quastel (1, 2). A 0.1 M sucrose and 0.1 M sodium potassium tartrate solution were used as the two solvents. One drop of Tween 81 was added to 1 ml of potato juice before placing forty microliters on Whatman No. 1 paper. This juice was allowed to dry on the paper before placing the filter paper in the solvent. In exploratory tests, no change in protein patterns was noticed when the damp spot was chromatographed immediately. The papers were removed from the second solvent, sodium potassium tartrate, and dyed in amido black 10B as previously described. A typical two-dimensional chromatogram is illustrated in figure 4.

RESULTS AND DISCUSSION

ELECTROPHOROGRAMS

Figure 1 shows the electrophorograms from the six healthy and six leaf-roll progeny of the second year indexing. The principal movement

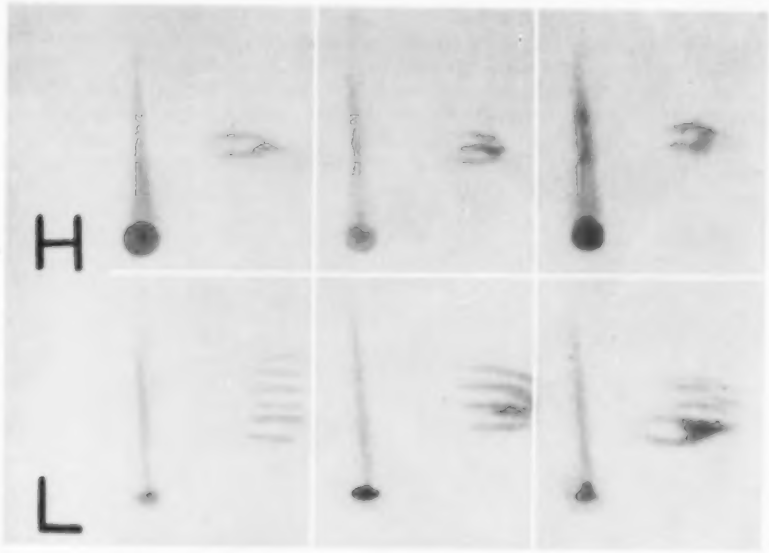

FIGURE 4.—Typical two-dimensional chromatograms from tuber juice of healthy and leaf roll Russet Burbank potato juice.

was towards the anode and shows a definite increase in total proteins in the leaf-roll samples. A comparison, with the one-dimensional chromatograms, shows essentially the same results. The electrophorograms were read on the densitometer and graphed. In figure 2A, a typical healthy and leaf-roll optical density curve is shown. It is noted that in the leafroll-infected sample there is an increase in the protein fraction carrying a more positive charge than is seen in the protein fractions of the control. Then, too, the more negative charged protein fraction also decreases. The data shown in table 1 indicate a significant increase in the total proteins for the virus-infected samples at the five per cent level.

TWO-DIMENSIONAL PAPER CHROMATOGRAPHY

Figure 4 shows typical two-dimensional chromatograms of healthy and leaf-roll tuber juice, selected from the 60 chromatographed in duplicate during the study. It is noted that the number of protein fractions from the healthy tubers is less than from the leaf-roll tubers. Whether or not one or more of these new fractions in the leaf roll samples is the actual virus protein has not been proved. Such proof might be difficult to obtain because of the nature of its transmission. These data seem to agree with those of Gray in that he also found additional fractions in tobacco plants infected with tobacco mosaic virus as compared with healthy controls. In making critical comparisons we selected paired samples of

healthy and leaf-roll material for comparison. In these paired samples all conditions from sampling through chemical determinations were the same. This included 27 paired samples in which the fractions were counted. In the healthy samples the number of fractions averaged 3.55 and in the leaf-roll samples 5.81.

ONE-DIMENSIONAL PAPER CHROMATOGRPHY

Figure 3 shows the difference between the leaf-roll and healthy protein fractions in one-dimensional chromatograms of the progeny of the second year's indexing. The same trends in the material from the first year's indexing were observed from tubers of the second year's indexing. It is noted that in all leaf-roll samples there was a greater amount of protein than in comparable healthy controls. Figure 2B shows an optical density scanning curve of a typical one-dimensional chromatogram for a healthy and leaf-roll sample. It is obvious from these curves that the fractions of the leaf-roll and healthy tubers differ both qualitatively and quantitatively. The one-dimensional chromatograms from the 6 healthy and 6 leaf-roll progeny of the second year indexing were read on the densitometer, graphed and the area measured with a planimeter, to determine the relative total proteins. These data are shown in table 1. The leafroll samples contained more total proteins than healthy samples. The difference was significant at the one per cent level.

TABLE 1.—*Effects of leaf-roll virus on the relative total proteins of Russet Burbank potatoes.*

		Relative Total Proteins			
		Electrophorograms		Chromatograms	
	No.	Area Units Sq. Inches	Difference from Healthy	Area Units Sq. Inches	Difference from Healthy
Healthy	6	2.70[1]		1.88	
Leaf Roll Virus	6	4.05	+1.35[2]	4.74	+2.86

[1]Planimeter measurements of areas under density curves. Each value is the mean of 6 replications.

	Electrophorograms	Chromatograms
[2]LSD at 0.05	0.91	1.71
LSD at 0.01	1.42	2.68

From the results of these studies it is apparent that it may be possible to develop a chemical detection technique for the qualitative and quantitative estimation of leaf-roll virus in potatoes, which is at least as dependable as winter greenhouse or winter southern field tests. Of the three techniques explored in this study the one-dimensional paper chromatographic procedure seems the most promising. This technique has been shown to give results very similar to paper electrophoresis and would be easier to adapt to a large-scale indexing program.

Before being adopted, this technique will require considerably more exploration. For example, an investigation of the behavior of other potato viruses is needed, particularly spindle tuber, rugose mosaic and mild mosaic. The behavior of particular potato varieties in relation to specific viruses should be studied. The relationship between time of infection by aphids carrying leaf-roll virus and the changes in both leaf and tuber proteins needs exploration.

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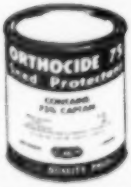

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NEWS AND REVIEWS

INTERNATIONAL POTATO CLUB CONFERENCE OF NORTHWEST EUROPE[1]

ORA SMITH[2]

The third biennial meeting of the International Potato Club of Northwest Europe was held in The Netherlands on August 8-11, 1955. The first two days were devoted to the presentation and discussion of a number of papers concerning the potato. These meetings were held at Wageningen, The Netherlands in a beautiful new hotel, "De Wageningse Berg", overlooking the Rhine River. The following two days were devoted to an excursion in the principal potato growing areas of The Netherlands.

The International Potato Club is an organization of potato research workers of Sweden, Denmark, Holland, Germany and England. It held its first meeting in Denmark in 1951. The second conference was held in England in 1953 and the third was conducted in 1955 in The Netherlands. This year there were about 80 research workers in attendance from the five above-mentioned countries. The author was invited to attend and present a paper on "Recent Developments in Potato Research in the United States".

The purpose of this club is to offer an opportunity for the research workers on potatoes in these countries to meet every two years and discuss their mutual problems and research results; to compare results on similar types of experiments and to avoid too much duplication of effort. This organization hopes to work more closely with the research workers in the United States through the Potato Association of America. I was appointed at this meeting to act as liaison between the two organizations and our efforts will be to accomplish the purpose set forth above. At this conference, they also expressed a desire to have greater exchange of ideas and the results of research. They look upon the Potato Association of America and its official publication, The American Potato Journal, as good models or examples of the goals they would like to reach. I'm sure all members of The Potato Association of America will agree that these are worthwhile ideals and that it is also to our advantage to encourage and help this group as much as possible to attain these goals.

PROGRAM OF LECTURES AT THIS CONFERENCE

On August 8 the following research workers presented the topics shown below:

1. "Recent Research in England on the Blackleg and Soft Rot Complex Diseases". Dr. A. R. Wilson, Director, Potato Storage Investigation, Sutton-Bonington, Eng.
2. "Recent Research on Potato Scab at the IVK". Dr. B. Emilsson, Institute for Plant Research and Cold Storage, Nynashamn, Swed.
3. "*Colletotrichum atramentarium* (Berk. and Bar.) Taubenh. on Potato Tubers". Dr. J. C. Mooi, Institute for Phytopathological Research, Wageningen, The Neth.

[1]Accepted for publication December 5, 1955.
Paper No. 400, Department of Vegetable Crops, Cornell University.
[2]Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

4. "Recent Developments in Potato Research in the United States", Dr. Ora Smith, Cornell University, Ithaca, N. Y., U.S.A.
5. "Testing of Machines, Especially with Regard to the Damage of Potatoes." Dr. Thoger Frederiksen, Director of the Agricultural Scientific Service of the Aktieselskabet De Danske Spritfabrikker, Svenstrup, Jylland, Den.
6. "New Developments in Building Potato Storages", Ir. B. G. Ophuis, Institute for Potato Storage, Wageningen, The Neth.
7. "Storage Experiments in a New Experimental Potato Storage at Studsgard", Mr. G. Gregersen, Statens Forsogsstation, Studsgard, Den.
8. "Potato Haulm Destruction in the Netherlands." Ir. A. J. Reestman, Central Institute for Agricultural Research, Wageningen, The Neth.

During the evening, tours were made to several of the Institutes in Wageningen, particularly the Potato Storage Institute and the Foundation for Plant Breeding.

On August 9 the following papers were given:

1. "The Application of Growth Promoting and Growth Inhibiting Substances on Potatoes and Their Effect on Storage of Seed and Ware." Dr. O. Fischnich, Direktor Institut fur Kartoffelbau und Saatguterzeugung, Braunschweig-Volkenrode, Ger.
2. "A Summary of Research on Sprout Inhibiting Chemicals in Sweden." Dr. B. Emilsson, Swed.
3. "Recent Work in England on the Use of Maleic Hydrazide for the Depression of Sprouting in Ware Potatoes". Dr. A. R. Wilson, Eng.
4. "Investigations with Growth Inhibiting Chemicals on Potatoes". Dr. J. Wolf, Bundesforschungsanstalt fur Lebensmittelfrischhaltung, Karlsruhe, Ger.
5. "Toxicology of Sprout Inhibiting Chemicals". Dr. H. van Genderen, Institut voor Volksgezondheit, Utrecht, The Neth.
6. "Chromatography of Potato Extracts for Determination of Growth Substances". Dr. W. G. Burton, Ditton Laboratory, Maidstone, Eng.
7. "Effect of Mineral Nutrition on the Biochemistry and Physiology of Potatoes". Dr. E. G. Mulder, Agricultural Experiment Station, T.N.O., Groningen, The Neth.
8. "Some Growing Conditions Influencing the Keeping Quality of Potatoes". Ir. P. A. Schippers, Institute for Potato Storage, Wageningen, The Neth.
9. "The Development of the Potato Plant During Its Growth". Miss Ir. N. Krythe, Institute for Potato Storage, Wageningen, The Neth.

Following the presentation and discussion of the above papers there was a two day excursion to many of the important potato-growing areas and research institutes. The following places were visited and the work in progress at each place was explained by the persons listed:

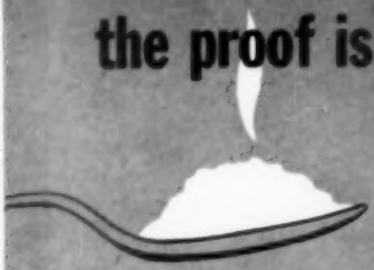
1. Storehouse of the Z.P.N. Cooperative at Emmeloord in the Northeast Polder. Potatoes stored in bulk. Speaker, Dr. W. H. deJong, Director of the Institute for Potato Storage, Wageningen and Secretary of the Potato Conference.
2. Storehouse of Hettema and Son, Ltd., Emmeloord. Speaker: Ir. B. G. Ophuis, Institute for Potato Storage.

3. Breeding farm of S.V.P., the so-called "Prof. Broekema-Hoeve" at Marknesse. Speaker: Ir. G. A. Thijn, Foundation for Plant Breeding, Wageningen, The Neth.
4. Trial farm of the N.A.K., the so-called "Dr. Oortwijn Botjes-Hoeve" at Emmeloord. Speaker: Ir. J. H. Brust, N.A.K., Wageningen, The Neth.
5. Trip to Leeuwarden through the province of Friesland.
6. Visited storehouse of Boomswa Ltd., at Berlikum. Speaker: Dr. W. H. deJong, Wageningen, The Neth.
7. Field trip to the trial farm of the regional inspection service of the N.A.K. at St. Anna Parochie. Serological research and application of the so-called "Igel-Lange Test" were demonstrated and explained to the group by Ir. G. W. Meyer.
8. Visit to the grading equipment of the Z.P.C. Cooperative at Harlingen.
9. Trip from Harlingen to Middenmeer along the enclosure dike of the Zuiderzee.
10. Visit to the Z.W.M. Cooperative at Middenmeer. A storehouse with refrigeration and a storing establishment with outside air-cooling was shown and explained to the group by Mr. K. H. Kroeze.

Most of the credit for the success of this conference and tour should be given to Dr. N. H. H. Addens, Chairman of the Board of the Institute for Potato Storage and President of the Club, and to Dr. W. H. de Jong, Director of the Institute for Potato Storage and very able Secretary of the Club.

I appreciated the honor of being chosen by the Conference officials to represent the potato research workers of the United States at these meetings. It was a pleasure to have the opportunity of listening to the presentation of research results from that part of the world and to take part in the discussion of these results. These meetings were interesting, instructive and inspirational. It was with a feeling of deep gratitude toward this group that I accepted the invitation of President Dr. Addens of the Netherlands and of Dr. Emilsson of Sweden to attend the fourth biennial Conference in Sweden in 1957.

the proof is in the eating



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ERRATUM:

Page 89, Figure 1 should be replaced with the figure shown below.

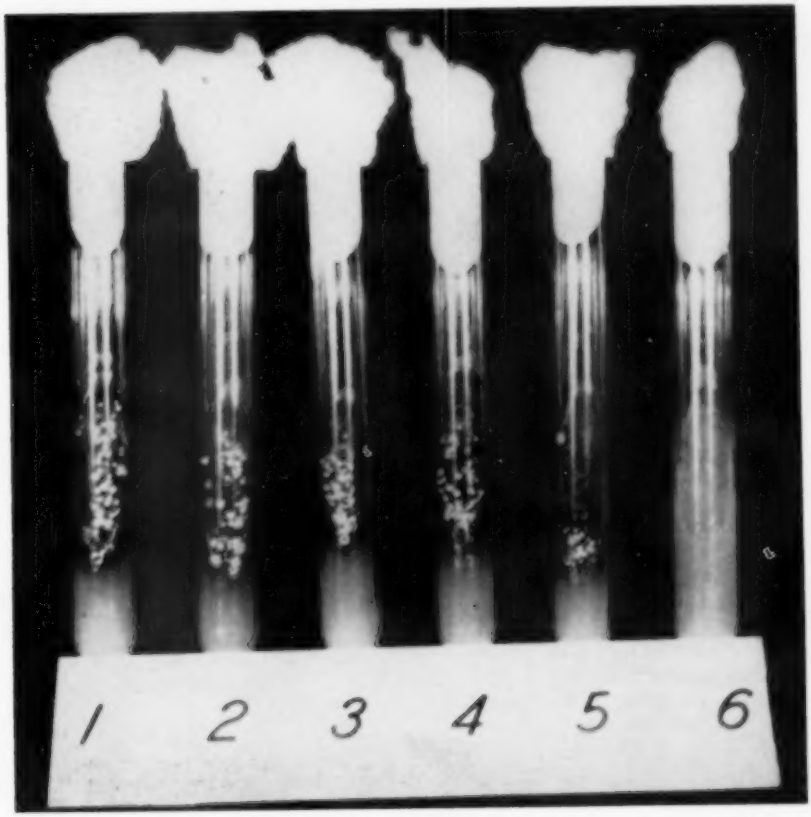

FIGURE 1.—Effects of aluminum acetate on the growth of *Streptomyces scabies* in potato agar. (1), Control; (2), 26 p.p.m. Al; (3), 50 p.p.m. Al; (4), 60 p.p.m. Al; (5), 80 p.p.m. Al; and (6), 100 p.p.m. Al.

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